During 2000, the Science Data Systems Branch (Code 586) continued to support the Earth and Space Science communities at the Goddard Space Flight Center by developing systems for science data capture, level-zero and higher-level data processing, data archival, data distribution, and information management. Branch members and supporting contractors were involved in numerous activities responding to the priority needs of the existing customers, as well as activities to establish new customers and to advance the leading edge of technologies needed to better perform these functions. The pace for the year was set by several major flight milestones: the launch of Terra in late 1999, the Hubble Space Telescope servicing mission 3A in late 1999, the launch of IMAGE (Imager for Magnetopause-to-Aurora Global Exploration) in March 2000, as well as Y2K.

The branch strives for recognition of its ability to appropriately utilize the latest technologies, existing COTS/GOTS products, cost-saving strategies, and current design and development methodologies. It hopes to establish its reputation for providing high-quality products: studies, consulting, prototyping, design, development, verification, and sustaining engineering. It attempts to do this in a way that is rewarding, challenging, and interesting for its members. We recognize these as essential ingredients in building a diverse, talented, innovative, energized, internationally recognized workforce of employees and managers.

In addition to delivering high-value products and services for ongoing projects, the Science Data Systems Branch is planning for future challenges in support of new, exciting NASA projects and missions. As the priorities of our current customers evolve and as we plan for a shift toward full-cost accounting, we realize the Branch may have to compete for much of its future work. This will necessitate careful nurturing of the core competencies of the Branch and an increase in the number of internal projects funded by proposals. We hope to establish a market for the Branch's capabilities. To be successful we will continue to maintain open, flexible, collaborative working relationships with customers and other partners.

Project, Laboratory, and Institutional Support

Branch members matrixed to projects, science laboratories, and institutional groups led the development of systems providing various levels of science and ancillary data processing starting from the point of the data reaching the ground until they are delivered to scientists or scientific data users for analysis. The systems ranged in complexity. At one end were those that handle single, small instrument data streams with a limited user community such as the LENA (Low Energy Neutral Atom), an instrument on the IMAGE. At the other end were the large multi-mission, distributed data systems serving diverse multi-disciplinary user communities such as the Earth Observing System Data and Information System (EOSDIS) which supports Terra data management.

Some of the major contributions to these groups follow:

Hubble Space Telescope (HST): The branch supported the HST servicing mission by managing response to anomalies, verifying mission orbits, and standing-by to ensure Y2K transition. A branch member also played a major role in the successful transfer of

HST operations to the Space Telescope Science Institute (STScI). Other branch members provided on-going sustaining engineering for the Vision 2000 Control Center System.

IMAGE/MAP (Microwave Anisotropy Probe): The branch provided ground systems communications support for these spacecraft. Another branch member provided on-going sustaining engineering for the IMAGE Level-Zero Product Generation System during testing and early launch in order to ensure adequate performance.

TRMM Science Data and Information System (TSDIS): The branch supported the development of Science Processor (SciPro), a flexible, portable system that processes raw science data in a serial fashion.

National Polar-orbiting Environmental Satellite System (NPOESS) Preparatory Project (NPP): The branch played key roles during mission formulation and definition, leading the development and acquisition efforts for the Science Data Segment and also instrument accommodations. These efforts led to a successful mission systems requirements review. This project presents new challenges with its interfaces with NOAA and DOD and utilization of high-performance instruments.

STEREO: The branch provided software systems engineering support and participated in a ground systems requirements review.

Earth Science Data and Information System (ESDIS): Much of the focus early in 2000 was in preparing to open the doors for public access to Terra data slated for mid-April. The branch supported science operations, development of various releases of the science data processing system, enhancement of information management capabilities, enhancement of the performance of level-zero processing, integration and testing. Personnel also continued planning for the upcoming Aqua mission by establishing interfaces with instrument teams, planning for storage and distribution of data, acquiring hardware, and performing operational simulations and other tests. The branch was involved in the successful Modified Antarctic Mapping Mission. Branch members interacted with the user community through participation in organizations such as the Earth Science Enterprise Federation (chairing various sub-committees) and user working groups. They also hosted seminars and workshops to train users in the use of tools for search, order, visualization, and manipulation of data and to define requirements for Application Program Interfaces to the EOS Clearing House (ECHO). They addressed various issues such as billing and accounting and long-term archive by conducting various prototypes.

LENA: The branch supported the LENA science team by developing image processing software, implementing science algorithms for monitoring the Earth, sun, perigee, and apogee, and developing a web-site to make the data and information easily accessible. Support was required for quick image quality assessment and data analysis during early instrument check-out and receipt of first light images.

Triana: The branch developed alternate options for a science operations center (TSOC) and managed ground system implementation. These efforts were reviewed by an independent science review board and in various requirements, system design, critical design peer, and pre-ship reviews.

Laboratory for High Energy Astrophysics (LHEA): The branch developed and maintained various web pages (for example Microwell project), supported Y2K conversion efforts, received and processed instrument data sets (such as TGRS and Konus).

Space Operations Management Office (SOMO): The branch supported standards efforts, administration and oversight of the Consolidated Space Operations Contract (CSOC), and various CSOC design and technology reviews. The standards efforts included on-going support for various CCSDS panels (1a,f, 2, 3), as well as managing a new effort for space link protocol testing using the Science and Technology Research Vehicle (STRV).

National Space Science Data Center (NSSDC): The branch led the development of a Java version of NSSDC's Common Data Format (CDF) tools and the conversion of documentation to a more easily maintained form.

Spacecraft Emergency Response System (SERS): The branch helped to transition this system from a research project into a commercialized product by instituting configuration management and change control and producing user and programmer documentation.

Integrated Mission Design Center (IMDC)*:* The branch provided science data systems engineering support for planning future missions such as Living with a Star Ionospheric Mapper Missions (IMM) and Inner Heliospheric Sentinels and Global Precipitation Mission (GPM).

Earth Science Technology Office (ESTO): The branch supports the management of winning proposals under the AIST NRA.

Science Data Systems Branch Products and Services

In addition to specific systems work, the branch pushed the leading-edge of information system technology and explored new information technologies. During 2000, Branch members participated in the development of prototypes involving new techniques for data display, data packaging, and development of reusable software libraries designed for the science community. They also responded to various calls for proposals to improve information management and assisting in planning the future vision for the Earth Science Enterprise. Several branch members were successful with their Independent Research and Analysis (IR&D) proposals and a Director's Discretionary Fund Proposal.

Many of these activities were supported by the QSS Group, Inc., under the Multidisciplinary Engineering Development Services (MEDS) Contract, and CommerceOne under various GSA IDIQ contracts.

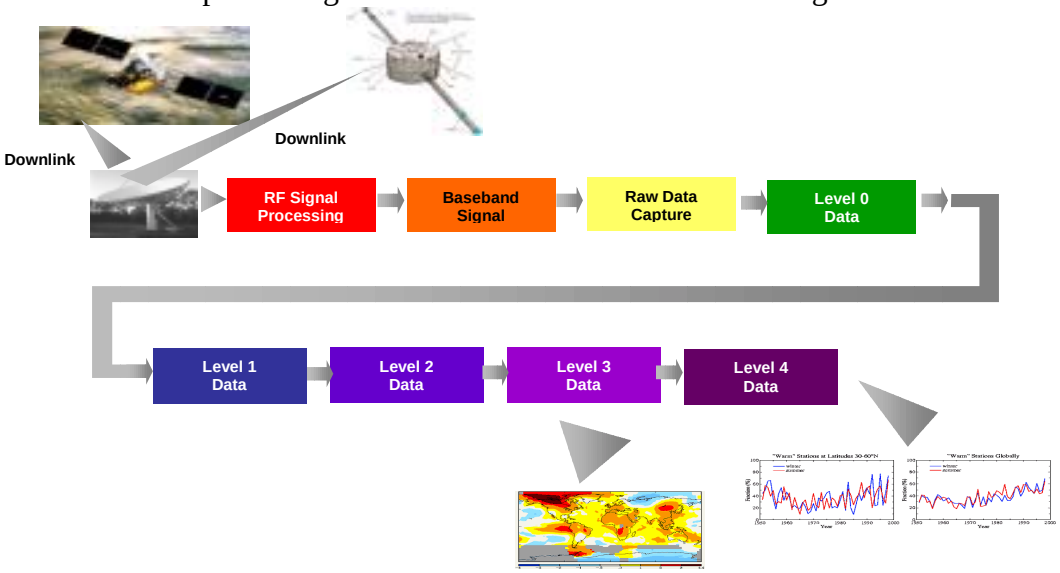
Science Data Processing Workshop 2000

The branch, in conjunction with the Advanced Data Management and Analysis Branch (Code 587) and scientists in the Laboratory for Extraterrestrial Physics (Code 690) hosted a successful Science Data Processing Workshop at GSFC. Over 170 software programmers/engineers, data system managers, project managers, scientists attended case

study presentations, poster sessions, tools and techniques sessions and participated in splinter sessions to develop ideas for improving science data processing.

Recommendations and next steps were developed by the splinter groups. A recurring next step from the splinters was to repeat the conference annually, and expanding participation to all NASA centers. This theme was repeated in the evaluations received. Other common themes for next steps included obtaining funding to develop toolkits and testbeds and a knowledge base for sharing information.

This first workshop was targeted to Goddard--over half of the registrants were Goddard



employees, most of the rest were contractors supporting GSFC projects, although there were a few from other NASA centers and other contractors. Over one-third of the attendees were affiliated with Code 500, another one-third from Code 900, one-sixth from Code 600, and the rest from Code 100, 400, and 700.

The workshop allowed these scientists and system developers to share tools, ideas, and data processing methodologies that form a common thread across disciplines, projects, missions, and instruments.

Mission Survey Database

The branch developed a tool that allows perusal and capture of mission characteristics with a standard browser: downlink data rates, data volume, mission sponsors, mission web site links, location of processed data sets. Developers can use this tool to identify commonality between existing missions and new missions, such as during planning sessions at the Integrated Mission Design Center. This allows us to ensure that whenever possible and practical, we take maximum advantage of the capabilities and/or inherent design features of existing, field-proven, and comparably-scaled ground systems, thereby reducing development costs.

Graphic with pull down menu

Science Data Processing Tutorial

In September 2000 the branch released a web-based, interactive Science Data Processing Tutorial (http://that.gsfc.nasa.gov/gss/tutorials/gsdp/index.html) that provides a detailed introduction to the functions necessary to capture real-time data from a typical NASA remote-sensing observing platform and perform all functions performed by the ground system. The goals of this effort were to help reduce the learning curve for new employees involved in science data processing, educate existing and potential customers to the technical issues associated with ground systems, and provide information to educate the general public.

Topics covered by the tutorial include an overview of the mission of the Branch, a description of the key elements of the communication infrastructure, the use of ground antennae, techniques of signal processing, and a description of the steps necessary for calculation of the science products. The tutorial is designed to be user-friendly, with the topics organized clearly and the various modules displayed with Macromedia Flash Player animations.

With the anticipation of additional staffing in 2001, we expect the tutorial to be especially useful for new employees hired directly out of college. Typically such persons are degreed in Computer Science or Software Engineering and would not have strong backgrounds in science data processing. The tutorial provides a broad overview of a mission along with necessary details. For example, in describing the ground system functionality the tutorial uses the Terra satellite and its payload as an illustration to explain basic terminology such as multiplexing, modulation, and telemetry. Aspects of baseband processing are also discussed in appropriate detail, including the bit synchronization, Viterbi decoding, frame synchronization, CRC checking, and the Reed-Solomon decoding steps.

Data Format Tutorials

During 2000 the Branch also released three web-based tutorials to assist and support programmers to develop applications to read and write science data using state-of-the-art formats. These tutorials address some of the salient characteristics of the more commonly used data formats that are produced by remote sensing ground processing systems in support of the Earth-, space, and planetary sciences. Included are tutorials for the Hierarchical Data Format (HDF) (http://that.gsfc.nasa.gov/gss/tutorials/hdf), Common Data Format (CDF) (http://that.gsfc.nasa.gov/gss/tutorials/cdf), Flexible Image Transport System (FITS) (http://that.gsfc.nasa.gov/gss/tutorials/fits). The tutorials provide detailed descriptions of these formats, their usage, and supporting software tools.

These tutorials are directed at new personnel needing to come up-to-speed on the use of a particular format, experienced personnel or existing or potential customers investigating which format would best meet a project's requirements, or the general public investigating ways to store data.

Image2000 Plug-Ins

We developed plug-ins for science data formats, FITS, CDF, and HDF, for Image2000--a cross-platform image processing system written in Java. Its use of the Java Advanced Imaging package provides it with a base set of over 75 image processing functions. In addition, a modular Directed Acyclic Graph (DAG) interface is provided for the iterative creation of new operations by combining and linking together existing operation. These new operations can be saved and edited so that they may be shared among the entire community of Image2000 users. This effort makes a powerful tool available to the science community as well as the educational community not usually familiar with the science formats utilized in NASA science data sets. (See 588's section.)

Beowulf Cluster Benchmarking

The branch implemented a Beowulf cluster -- a low-cost cluster of workstations working cooperatively to process science data at super-computing speeds--using recycled and/or excessed personal computers and public-domain and open source software. We expect this cluster to help us better understand how to accelerate science data processing applications for downlinked spacecraft data, process larger volumes of data, or process data in flight among a constellation of satellites. Initially, we implemented a probabilistic Neural Network (PNN) data processing algorithm and obtained 15 times speedup using 16 nodes.

Constellation Management

We have been studying the science data processing needs and concerns in the upcoming era of both nanosat and constellation type missions. As a result we developed a white paper which provided recommendations and approaches to this new mission scenario. It is clear from an examination of the issues that the linear scaling expected from on-going advances in technology will not produce cost effective solutions, and a new paradigm will be needed. The issues must first be examined for the homogeneous instrument set; but it is expected that this will quickly turn to heterogeneous sets as equipment drifts and degrades or as experiments are devised which require heterogeneous instruments. The branch worked with the constellation management working group, contributing to the group's white paper and maintaining a central repository.

OPUS Testbed

The branch recognizes the need to take advantage of existing products, such as the STScI's (Space Telescope Science Institute) OPUS Data Processing System--an automated data pipeline processing environment. Although OPUS was developed to

manage the hundreds of exposures taken by the Hubble Space Telescope each day, it has proven to be sufficiently generic for application to many other missions and projects (AXAF (Chandra), SIRTF, and FUSE). Therefore, we installed OPUS and Ftools (tools for creating FITS products) in the Science Data System Laboratory for use as a testbed for future projects. Our experience with installation and tests with sample data allowed us to produce a more informed feasibility study for SWIFT, and to demonstrate the product to the XTE project team.

Flatsat Testbed

We initiated studies of potential for on-board science data processing with the intent to demonstrate the integration of a selected science data processing algorithm into Code 588's existing FlatSat Architecture. We will want to show data volume reduced/time, process followed to integrate into the existing architecture, problems encountered, pros/cons and potential limitations on utilizing this on a future flight mission and suggest any ROM cost savings gained. We realize that we must show a significant value-added in order for scientists to be willing to risk the loss of data or potential to correct data in the future.

Outreach

Branch members were very active in their communities. Several participated in Science Fairs at local schools and others made classroom presentations about their work. For example, one branch member presented her work to science/physics classes at Poly Tech High School in Baltimore, another to DeVual High School students**.** Another was the National Judge for the NAACP's 23RD Annual Afro-American Cultural, Technological and Scientific Olympics held at the Baltimore Convention Center. The branch also participated in various programs, such as the High School for High Tech--a program that actively recruits young people with disabilities and facilitates greater exposure and interest in high technology fields. A student from this program worked with one of our branch members during the summer to develop a web site. Another branch member collaborated with Bowie State University on the WIRE Testbed, allowing students to obtain operational experience. We also participated in the Center's annual Take Our Daughters to Work Program.

Branch members presented papers at various conferences, workshops and symposia. These include *SPIE's 14th Annual Symposium*, the 8th NASA Goddard Conference on Mass Storage Systems and Technologies in cooperation with the 17th IEEE Symposium on Mass Storage Systems, 4th AMASS Users Group meeting, Geographical Information Systems for Information Systems Professionals Symposium at Ohio State University, and IEEE International Geoscience and Remote Sensing Symposium (IGARSS) 2000.NASA, and the Institute for Advanced Studies Conference.

The branch has also recruited at various universities, including Towson State University and Massachusetts Institute of Technology, and career fairs, such the annual Society of Women Engineers Conference.

Outlook for 2001 and Beyond

Although support for existing projects, such as ESDIS, NPP, and HST, is expected to continue for several years, we will also be allocating resources to new projects. We anticipate new work for programs related to scientific modeling, such as Living With A Star and High Performance Computing and Communications, and for knowledge-discovery efforts such as NASA's Environment & Health Initiative and support to the Intelligent Data Understanding project. Work is also anticipated for future projects that will require constellation management and event-responsive data collection. For these new activities the Branch would provide software engineering services and would participate in the development of interface applications. Branch personnel would likely team with members of the Advanced Data Management and Analysis Branch and the Advanced Architectures and Automation Branch to ensure the necessary mix of skills are provided to the customers.

Beginning in January 2001 Branch management and staff will develop a strategic plan that will formulate a long-term roadmap for project support. The importance of the strategic planning effort is underscored by the anticipation of significant changes to the types of customers and the projects in this timeframe. Some of these include:

- A migration away from centralized ground data processing. For many future missions the Principal Investigators will perform this activity. The Branch will thus be expected to be a center of excellence for ground data processing, and must be able to provide the necessary synergy among the diverse science projects.
- New support for developing "event responsive" acquisition of science data. Future constellations of satellites will have the ability to be triggered by predictive models and external observations for capture of specified science events.
- New support directed toward science data modeling. The Branch will assist the Earth and space scientific modeling efforts by instilling software engineering practices in the development and maintenance of codes and by designing application interfaces such that modeling components built by various institutions can interoperate.
- Development and implementation of tools for knowledge discovery of science data. Branch members will work closely with personnel from the Advanced Data Management and Analysis Branch to develop application interfaces for use in data mining efforts.

The branch will continue to focus on developing internal technical projects that will help to advance the core competencies necessary for us to be successful in these areas. This will involve part-time work from matrixed staff, contractors, and teaming arrangements with personnel from other branches within the ISC.

Contacts

Michael Seablom, Head
Science Data Systems Branch
Code 586
301-286-2406

Mary Reph, Associate Head
Science Data Systems Branch
Code 586
301-286-1006